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RESEARCH MEMORANDUM

DETERMINATION OF AIRCRAFT ANTENNA LOADS PRODUCED BY NATURAL ICING CONDITIONS

By William L. Kepple

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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DETERMINATION OF AIRCRAFT ANTENNA LOADS PRODUCED BY NATURAL ICING CONDITIONS

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SUMMARY

A flight investigation was made to determine the effect of distance flown in the icing region, antenna length, and antenna angle on the tension occurring in aircraft antennas while in regions of aircraft icing.

The experimental antennas were of lengths ranging from 15 to 43 feet and were placed at angles of 0° to 64° with the airplane thrust axis. Distances up to 256 miles were flown in diverse icing conditions at true airspeeds from 15'7 to 214 miles per hour and pressure altitudes at which icing conditiona were encountered.

The results indicate that: The effect of ice formation on antenna tension increased with the angle of the antennas with the longitudinal axis of the airplane. The maximum tension for antennas having angles from 0° to 15° was 68 pounds, whereas the maximum tension for antennas having angles of 44° and 64° was 274 and 436 pounds, respectively.

INTRODUCTION

The current use of improved airplane foe-prevention equipment has extended operations in icing conditions and thus accentuated the need for protecting aircraft antennae against structural failures resulting from ice accretions. A flight investigation was therefore conducted at the NACA Cleveland laboratory to determine the tension in aircraft antennas produced by ice formations.

The investigation was conducted in natural icing conditions over a range of true airspeeds from 157 to 214 miles per hour and altitudes from 3500 to 9500 feet. Seven experimental antennas of lengths ranging from 15 to 43 feet were placed at angles of 0° to 64° with the thrust axis of the airplane. The effect of the following factor8 on the antenna tension was investigated: antenna length, included angle between the antenna and the thrust axis of the airplane, and distance flown in the icing region.

APPARATUS AND PROCEDURE

The location of the seven experimental antennas on the airplane is shown in figure 1; the length and the angle of each experimental antenna are also presented and are listed in the following table:

Antenna angle (deg)	Antenna length (ft)
64	40
44	42
15	43
15	32
15	15
8	41
0	41

Inasmuch as it was anticipated that the tension which would be imposed on the antennas would exceed the breaking strength of the ordinary antenna wire, the experimental antennas used were of 1/16-inch diameter, 7 by 7, aircraft-control cable. Turnbuckles and spring-tension units were mounted on the rear of the antennas (fig. 2) in order to impose a static tension of 30 pounds.

The t&ion in the antennas was measured by strain gages located at the front of the antennas (fig. 3). The strain gages were temperature-compensating and were sealed in order to keep them moisture-free. Electrically heated anti-icing boots were installed around the body of the strain gages. A recording galvanometer indicated the tension in the antennas. The strain-gage system was accurate to ±2 percent.

Multirotating cylinders, as shown in figure 4, were used to determine the average droplet diameter, the drop-size distribution, and tbe liquid-water content. These cylinders were similar to those used in reference 1 with minor mechanical modifications. Pressure altitude and indicated airspeed were measured by service instruments and the ambient-air temperature was measured by a shielded resistance-bulb thermometer.

A series of four flights was conducted into areas of predicted icing. Table I presents the meteorological conditions for the respective flights. The values shown in this table are the averages of individual values recorded at intervals throughout

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each flight operation. The notation for the drop-size distribution corresponds to that given in reference 1, table I, page 6. The factors that made possible the existence and the suspension of supercooled liquid-water droplets encountered during the flight operations are presented in the appendix.

RESULTS AND DISCUSSION

Photographs of ice configurations on the 8°, 41-foot antenna and the 15°, 32-foot antenna are presented in figures 5 and 6, respectively, and are representative of ice formations on antennas having angles from 0° to 15°. Figure 7 is a photograph, taken in flight, of the ice formation on the 15°, 32-foot antenna and the 64°, 40-foot antenna. The ice configuration on the 64°, 40-foot antenna is illustrative of configurations collected on the 64°, 40-foot and the 44°, 42-foot antennas during most of the flight operations.

The variation of antenna tension with distance flown in the icing region for the antennas is presented in figure 8 for the four flight operations. The shaded areas on the figures for the 64°, 40-foot and 44°, 42-foot antennas represent the maximum and minimum tensions produced by whipping. The variation of antenna tension due to whipping for the 0° and 15° antennas was insignificant. Figure 8 shows that, in general, for the 44° and 64° antennas, antenna tension increases considerably with the distance flown in the icing region; whereas, for the antennas of 15° and less, the variation of tension with distance is insignificant. The change in the slope of the antenna-tension curve from positive to negative indicates that whipping of the antennas broke off ice formations and thereby temporarily reduced the antenna tension.

The variation of antenna tension with antenna a-ogle for antennas of approximately 42 feet in length is presented in figure 9. The tension values presented in this figure were obtained from figure 8. Figure 9 indicates that the antenna tension increased with increasing antenna angle for antennae of nearly constant length. With increasing angle, the antenna tension increased eight times faster in the 44° to 64° range than in the 0° to 15° range. The slope of the curve for antenna angles greater than 15° indicates that the required antenna strength increases rapidly as the antenna angle is increased beyond 15°. The investigation presented in reference 2 also recommends a limiting antenna angle of 15°. The variation of antenna tension with antenna length at a constant antenna angle of 15° is presented in figure 10. The

data were obtained from figure 8 and indicate that the tension increases nearly linearly with antenna length. The maximum tension measured for each of the seven experimental antennas during the four flight operations is given in table II.

SUMMARY OF RESULTS

From an analysis of the tension occurring in aircraft antennas during flights in regions of aircraft icing made for antennas with angles to the thrust axis of the airplane of 0°, 8°, 15°, 44°, and 64° and lengths from 15 to 43 feet, the following results were obtained:

1. The tension in the 44° and 64° antennas increased considerably with distance flown in the icing region, whereas the tension for antenna angles of 15° and less did not increase appreciably with distance flown in the icing condition.

2. The rate of change of antenna tension with antenna angle in the 0° to 15° range was one-eighth the rate of change of antenna tension with antenna angle in the 44° to 64° range. The slope of the curves of tension as a function of antenna angle begins to change appreciably above 15°, which indicates that the required strength of antennas will increase rapidly if the antenna angle is increased beyond 15°.

3. Antenna tension varied approximately linearly with antenna length.

4. The maximum recorded tension for the 0° to 15° antennas was 68 pounds. The maximum tension for the 44° and 64° antennas was 274 and 438 pounds, respectively.

Flight Propulsion Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio.

APPENDIX - METEOROLOGICAL HISTORY OF FLIGHT OPERATIONS

Flight operation 1. - This flight was conducted in a region having meteorological conditions that resulted from: (1) a convergence of several air masses; (2) the lifting of relatively warm, moist air over the upper cold frontal surface; and (3) an unstable condition in the lower 4800 feet. These factors made possible the existence and suspension of supercooled liquid-water droplets.

Flight operation 2. - Flight operation 2 was conducted in an area ahead of cold-front weather. The suspension of supercooled liquid-water droplets was enhanced by the following factors: (1) a strong convergent air flow in the deepening pressure system associated with the front; (2) a temperature inversion through which a strong vertical ascent of saturated air occurred; and (3) the evaporation of melting snow plus an unstable lapse rate to the cloud base.

Flight operation 3. - The flight was made into a region dominated by a deck of altostratus clouds caused by the overrunning of maritime tropical air over a quasi-stationary continental polar front. The flight was conducted near the northern periphery of the precipitation area, in which it appeared that nearly colloidal unstable conditions existed.

Flight operation 4. - This flight was conducted in a convective-type cloud of limited geographical extent. Strong vertic81 air motion carried the cloud tops several hundred feet above the temperature inversion, which was conducive to the suspension of a large amount of supercooled water droplets in the cloud.

REFERENCES

1. Vonnegut, B., Cunningham, R. M., and Katz, R. E.: Instruments for Measuring Atmospheric Factors Related to Ice Formation on Airplanes. M.I.T., De-Icing Res. Lab., April 1946.

2. Haller, George L.: Icing of Aircraft Antenna Wires. Jour. Aero. Sci., vol. 6, no. 1, Nov. 1938, pp. 27-28.

TABLE I - FLIGHT AND METEOROLOGICAL VARIABLES

Flight operation	Distance in icing region (miles)	Pressure altitude (ft)	Ambient-air temperature (°F)	Droplet diameter (microns)	[a]Drop-size distribution	Liquid-water content (g/cu m)
[illegible]	153	3500	26	8	E	0.25
2	115	3700	25	13	E	.30
3	256	9500	20	18	E	.21
4'	121	5700	21	15	A	.26

[a]See reference 1, table I, page 6.

TABLE II - MAXIMUM ANTENNA TENSION

[illegible]	Antenna angle (deg)	Antenna length (ft)	Antenna tension (lb)
[illegible]	64	40	438
	44	42	274
	15	43	68
	15	32	57
	15	15	43
	8	41	56
	0	41	50

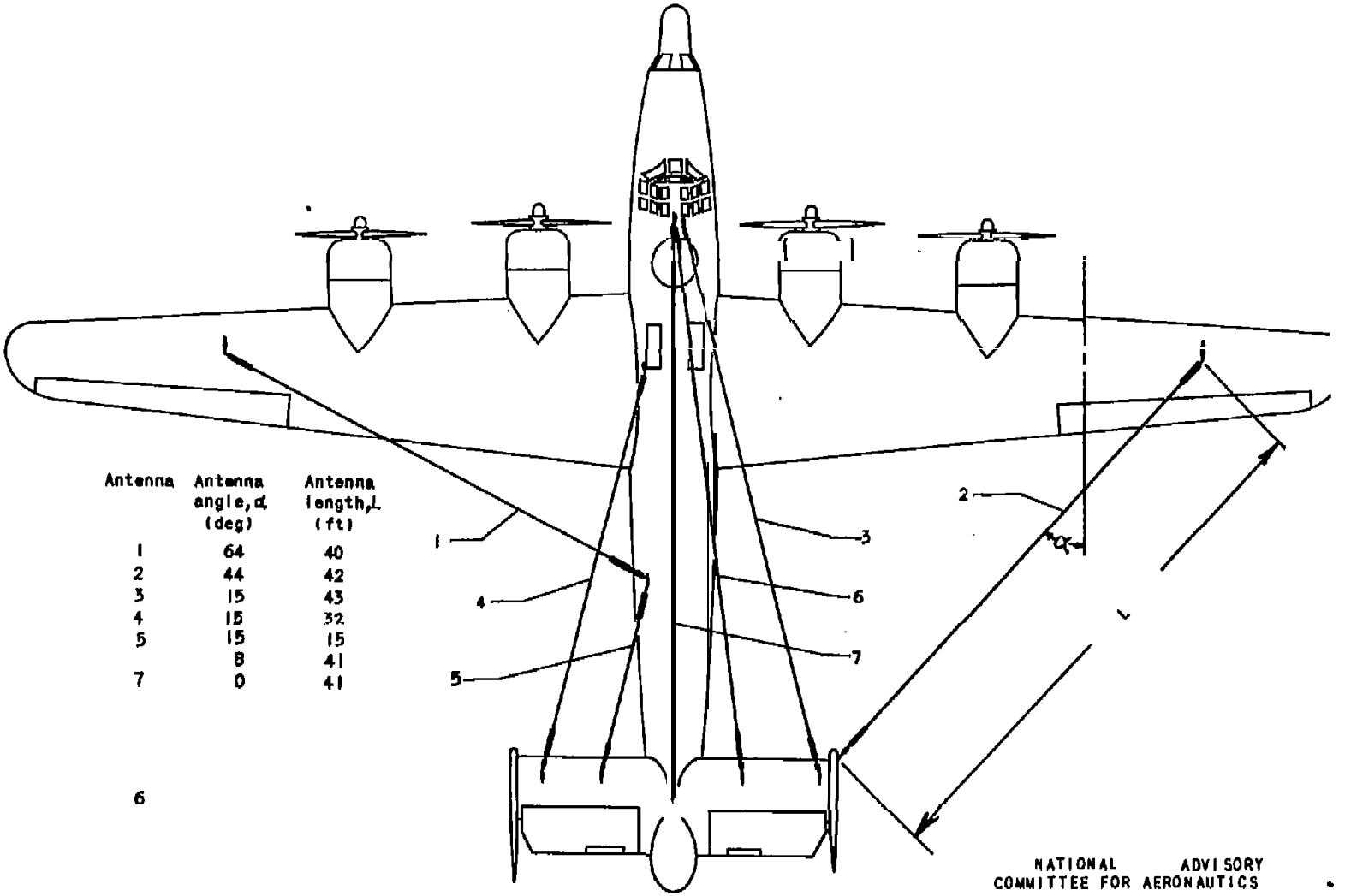

Figure 1. - Location of experimental antennas on airplane and angle and length of antennas.

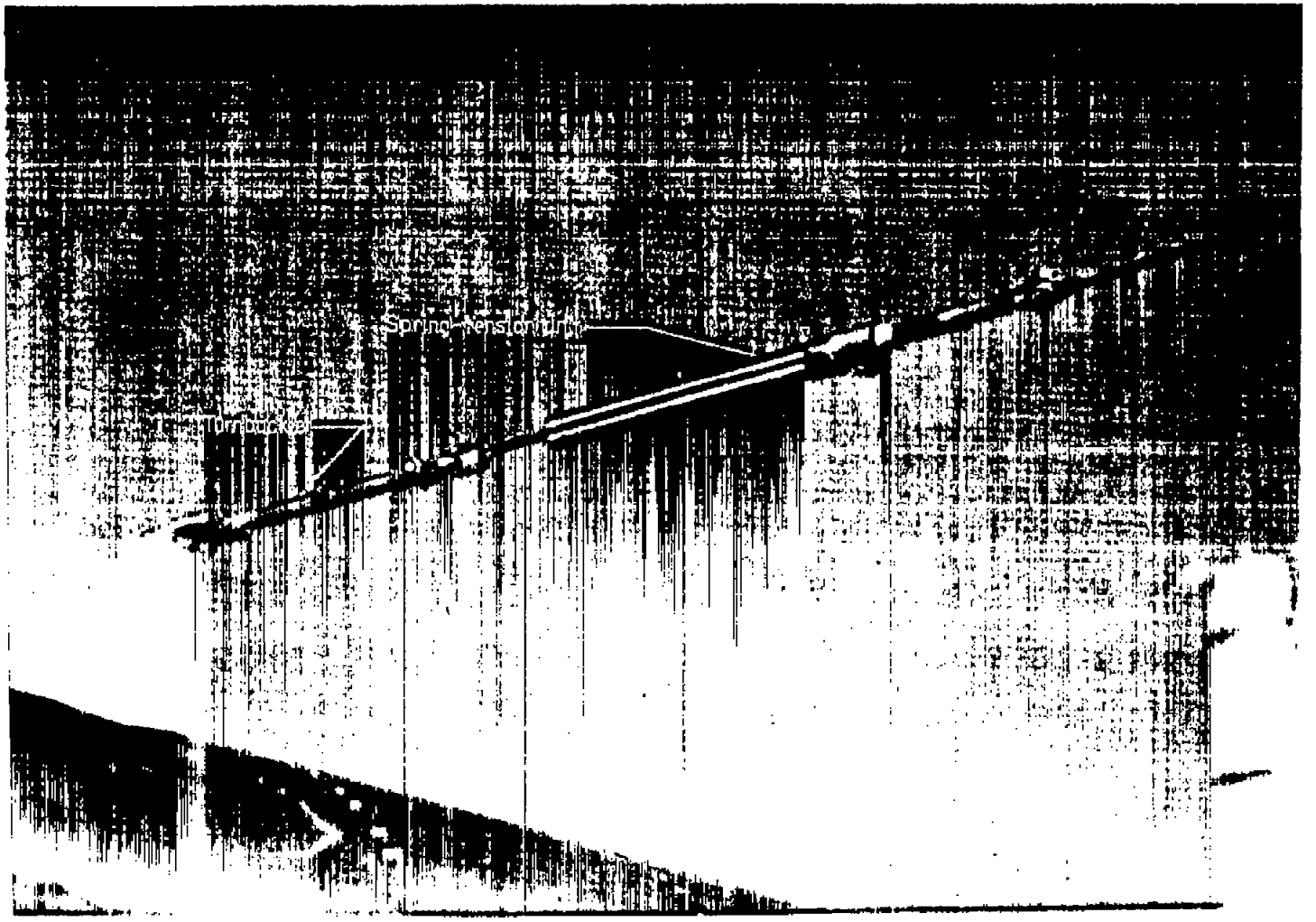

Figure 2. - Turnbuckle and sprlng-tenslon unit mounted on rear of experimental antenna.

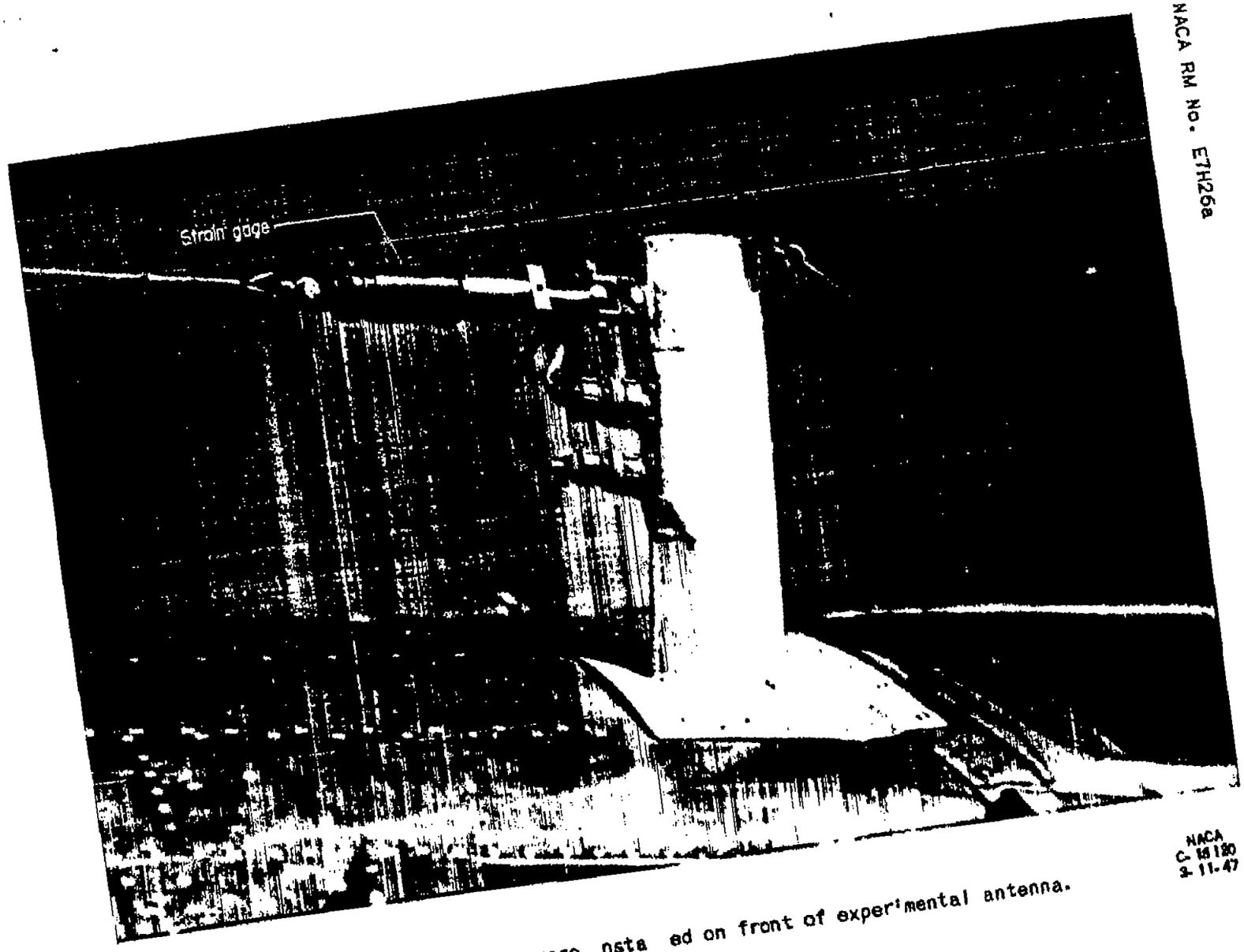

Figure 3. - Strain gage installed on front of experimental antenna.

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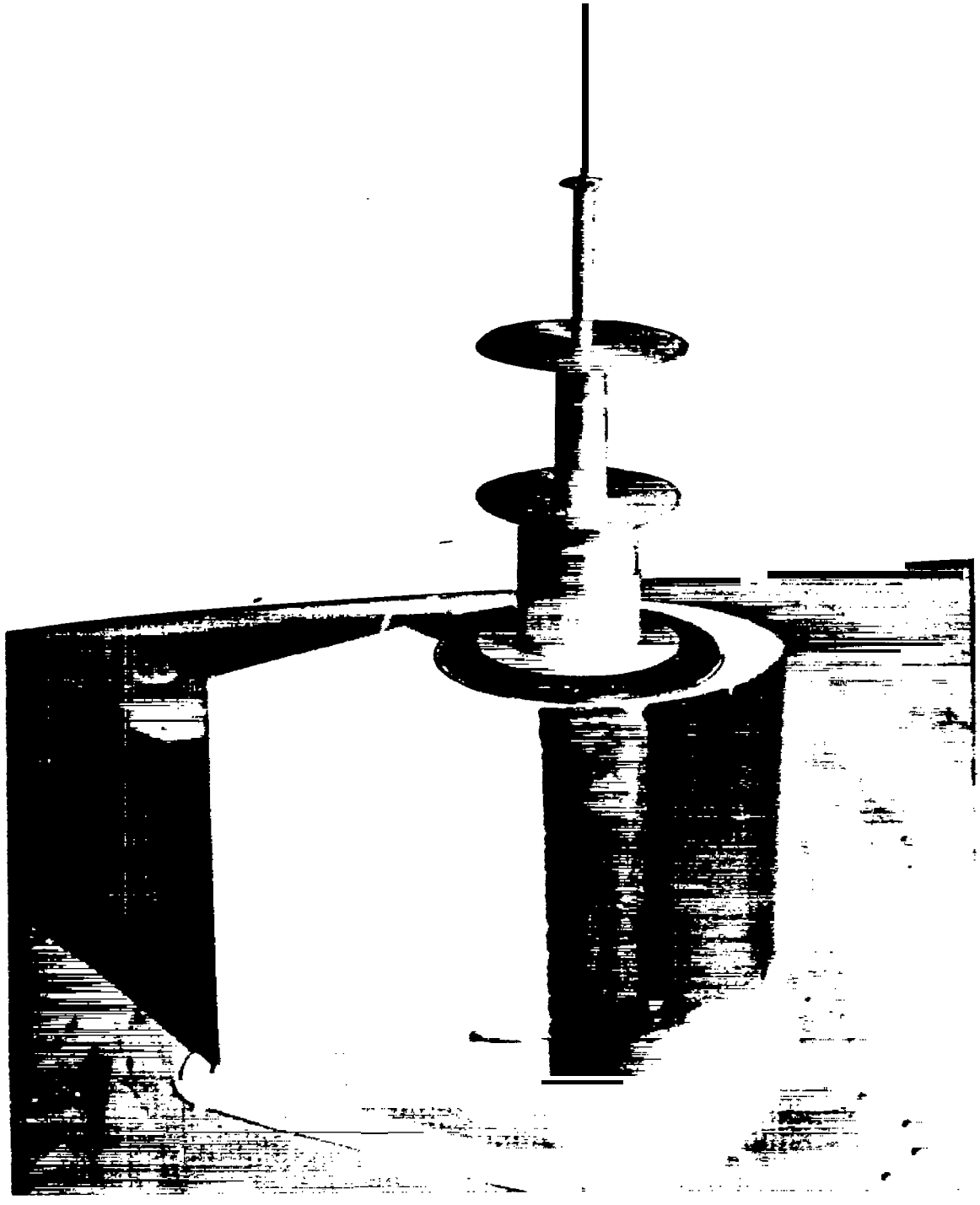

Figure 4. - Multi rotating cyl inder extended into air stream for col lec- tion of meteorological data.

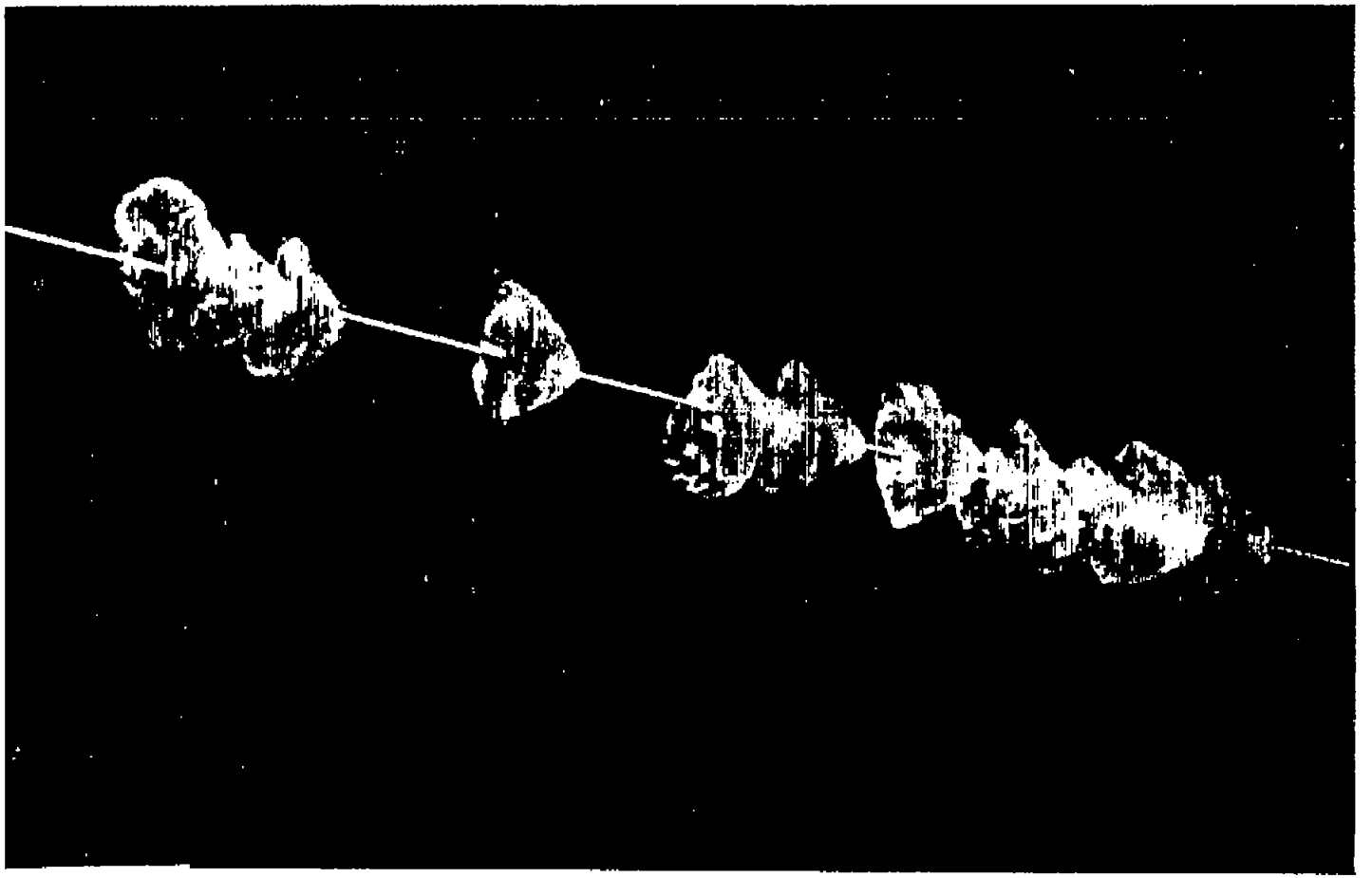

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Figure 5. - Typical ice formation collected on 8°, 41-foot antenna during flight. Air flow from left to right.

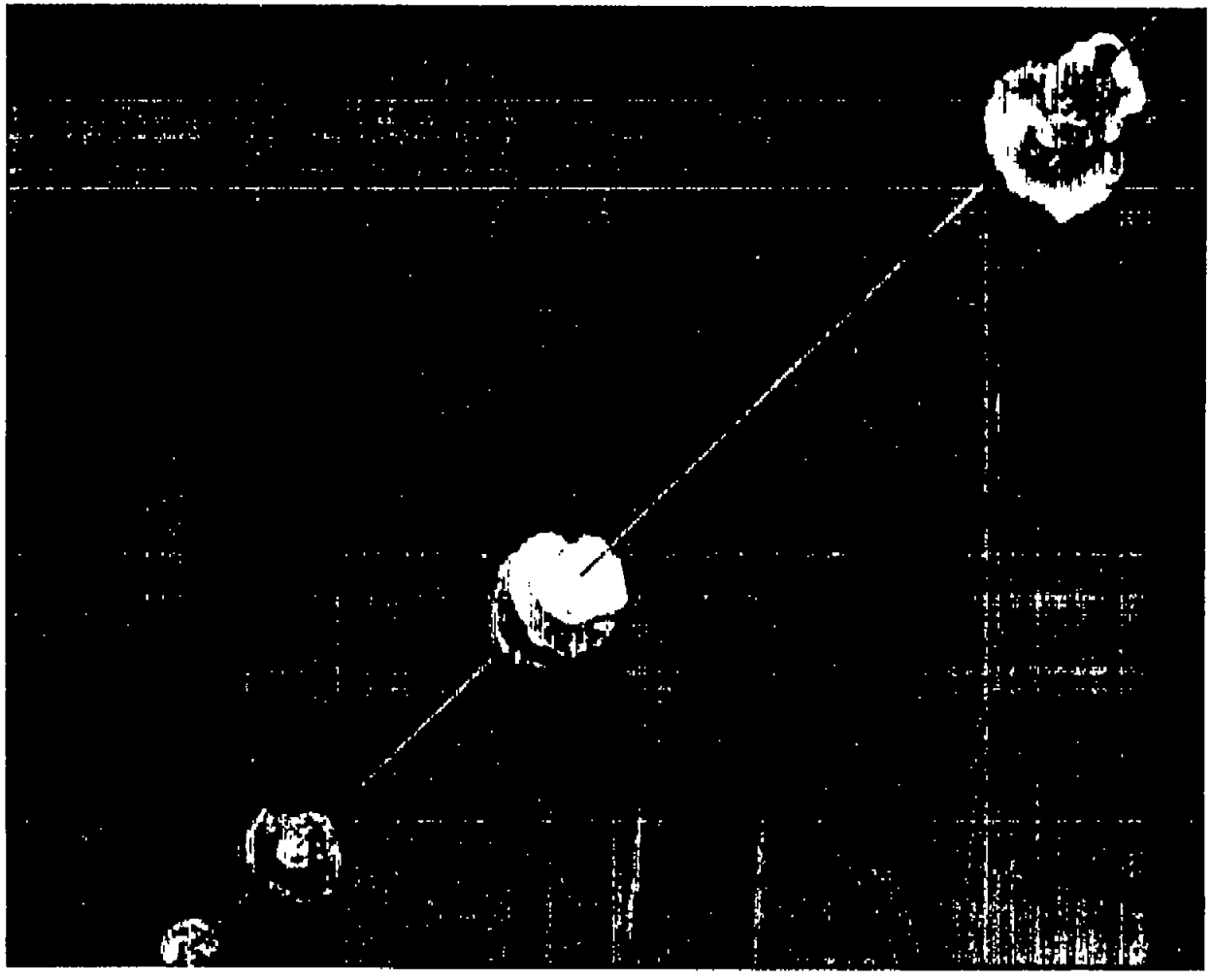

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Figure 6. - Typical ice formation collected on 15°, 32-foot antenna during flight. View looking aft.

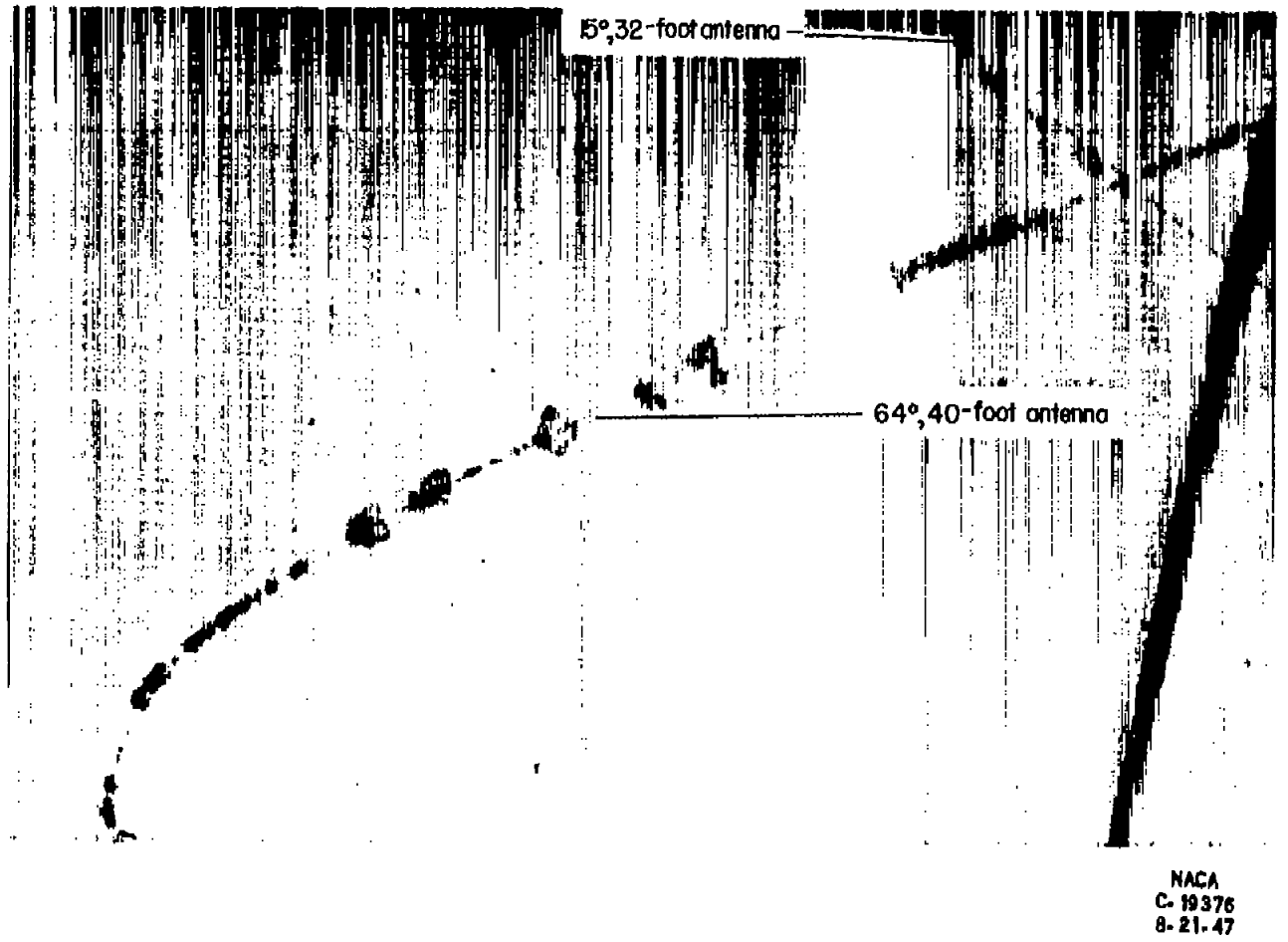
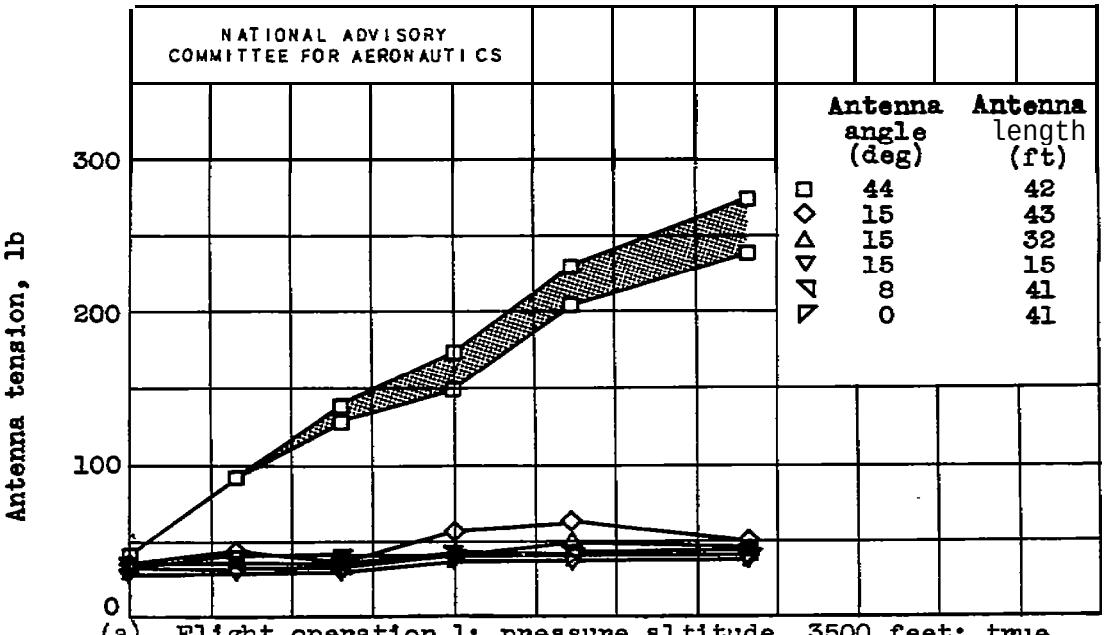
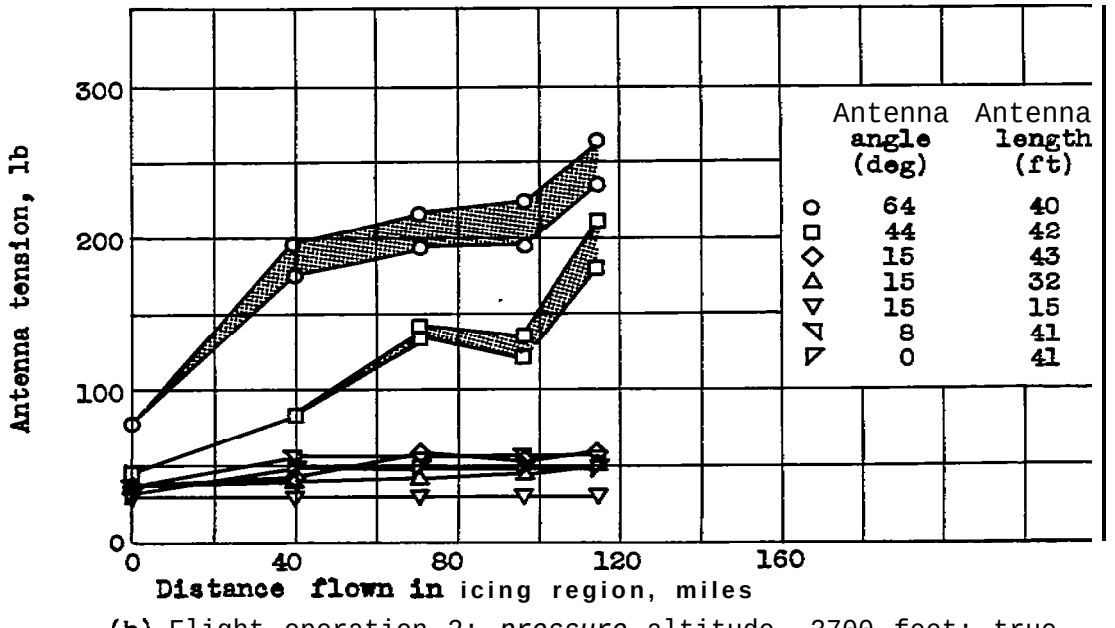


Figure 7. - Typical Ice formations collected during flight on 15°, 34-foot antenna and 64°, 40-foot antenna. View underneath antennas, looking forward.

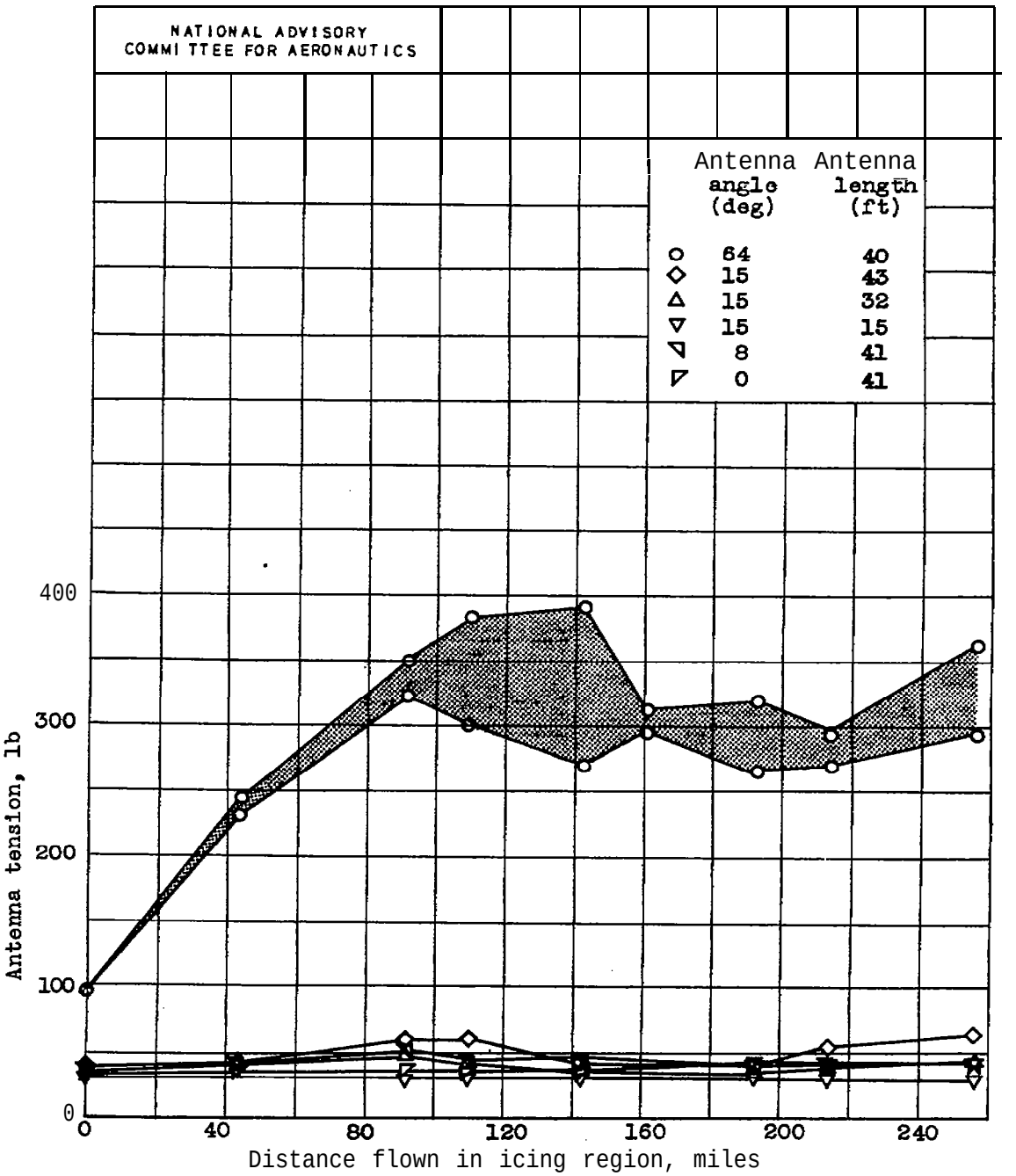


(a) Flight operation 1; pressure altitude, 3500 feet; true airspeed, 155 miles per hour: ambient-air temperature 26° F; liquid-water content,-0.25 grams per cubic meter; average droplet diameter, 8 microns; 64°, 40-foot antenna not installed for the flight operation.



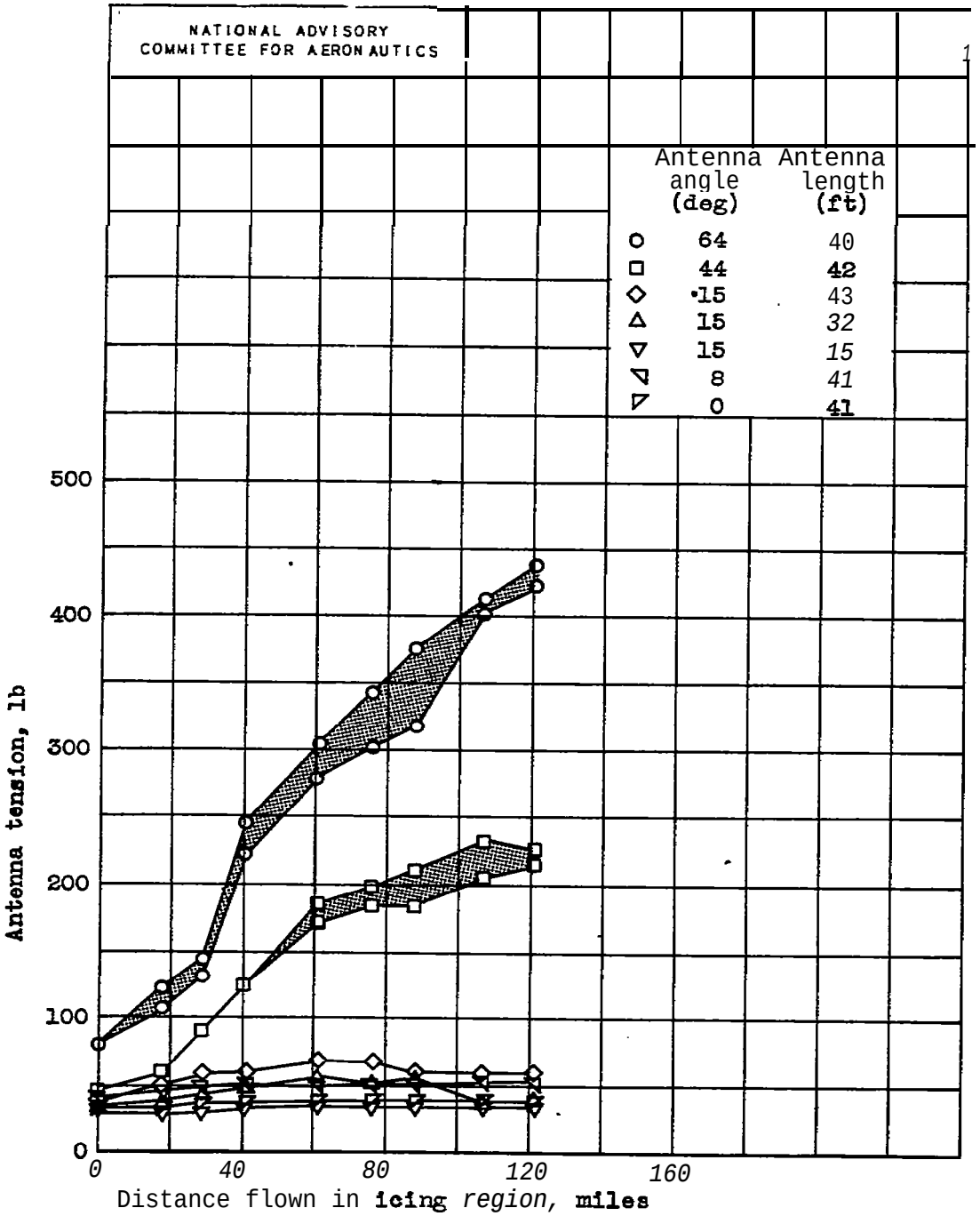
(b) Flight operation 2; *pressure* altitude, 3700 feet; true airspeed, 177 miles per hour; ambient-air temperature, 25° F; liquid-water content, 0.30 grams per cubic meter; average droplet diameter, 13 microns.

Figure 8. - Variation of antenna tension with distance flown in icing region for experimental antennas.



(c) Flight operation 3; pressure altitude, 9500 feet; true airspeed, 214 miles per hour; ambient-air temperature, 20° F; liquid-water content, 0.21 grams per cubic meter; average droplet diameter, 18 microns; data for 44°, 42-foot antenna not obtained owing to strain-gage failure.

Figure 8. - Continued. Variation of antenna tension with distance flown in icing region for experimental antennas.



fd) Flight operation 4; pressure altitude, 5700 feet; true airspeed, 182 miles per hour; ambient-air temperature, 21° F; liquid-water content, 0.26 gram per cubic meter; average droplet diameter, 15 microns.

Figure 8. - Concluded. Vat-ration of antenna tension with distance flown in icing region for experimental antennas.

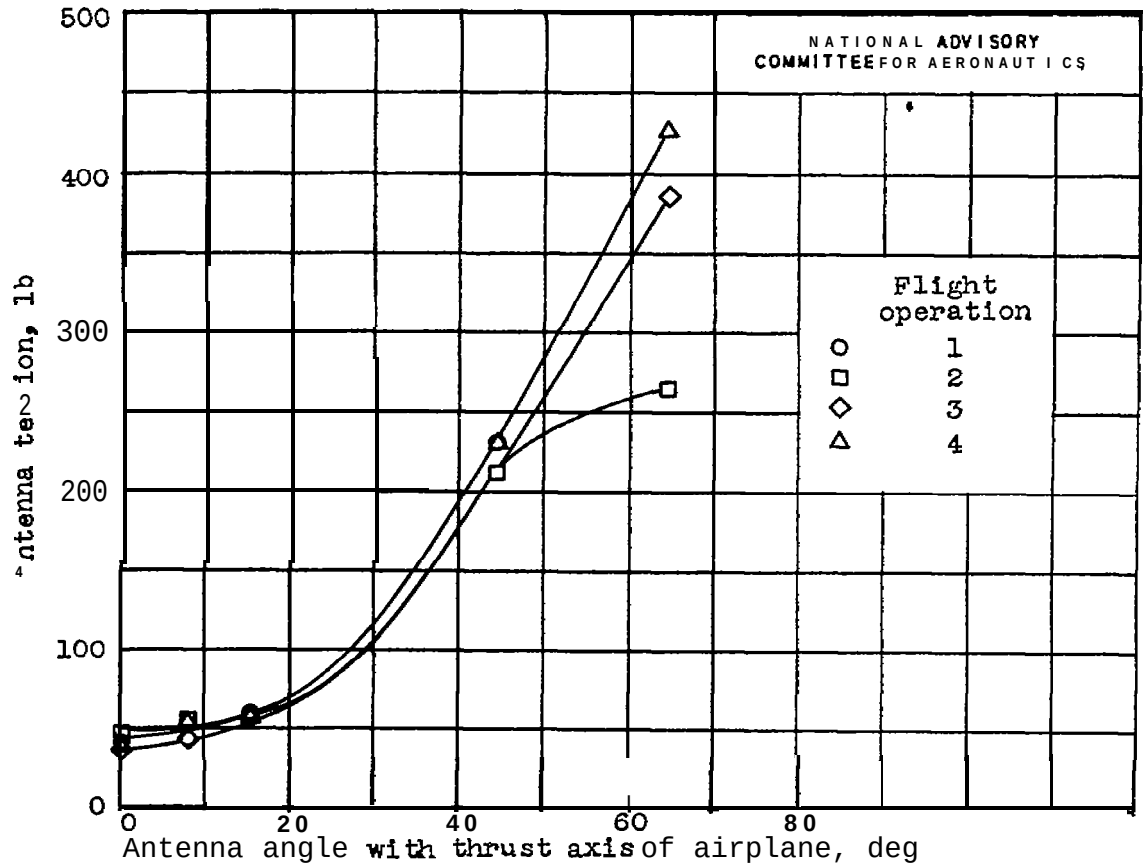


Figure 9. - Variation Of antenna tension with antenna angle for antennas of 40, 41, 42, and 43 feet in length. Distance flown in icing region, 115 miles.

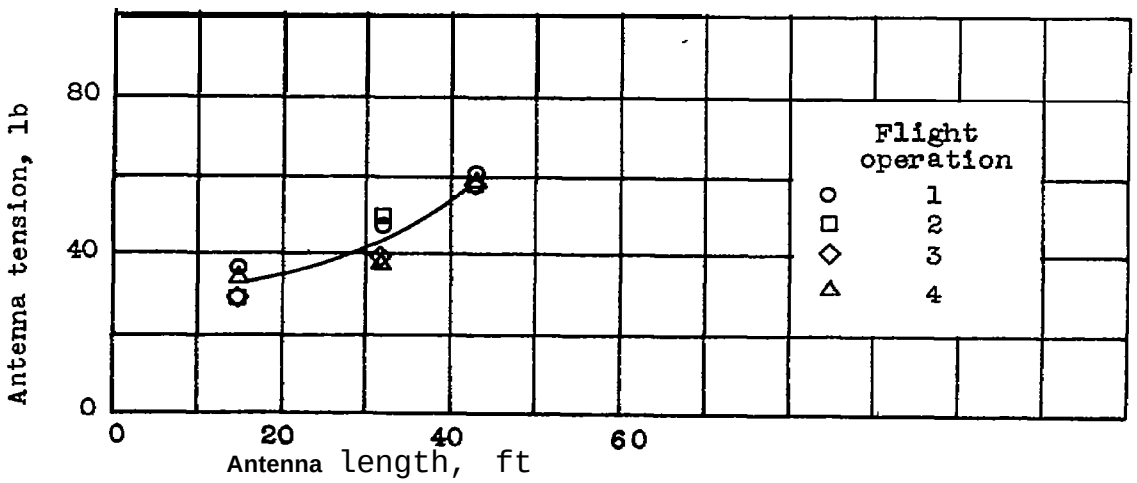


Figure 10. - Variation of antenna tension with antenna length at antenna angle of 15°. Distance flown in icing region, 115 miles.

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